Langley Research Center

Illuminating albedo: using MOSAiC data to assess the CERES Cloud Radiative Swath (CRS) albedo quantification process

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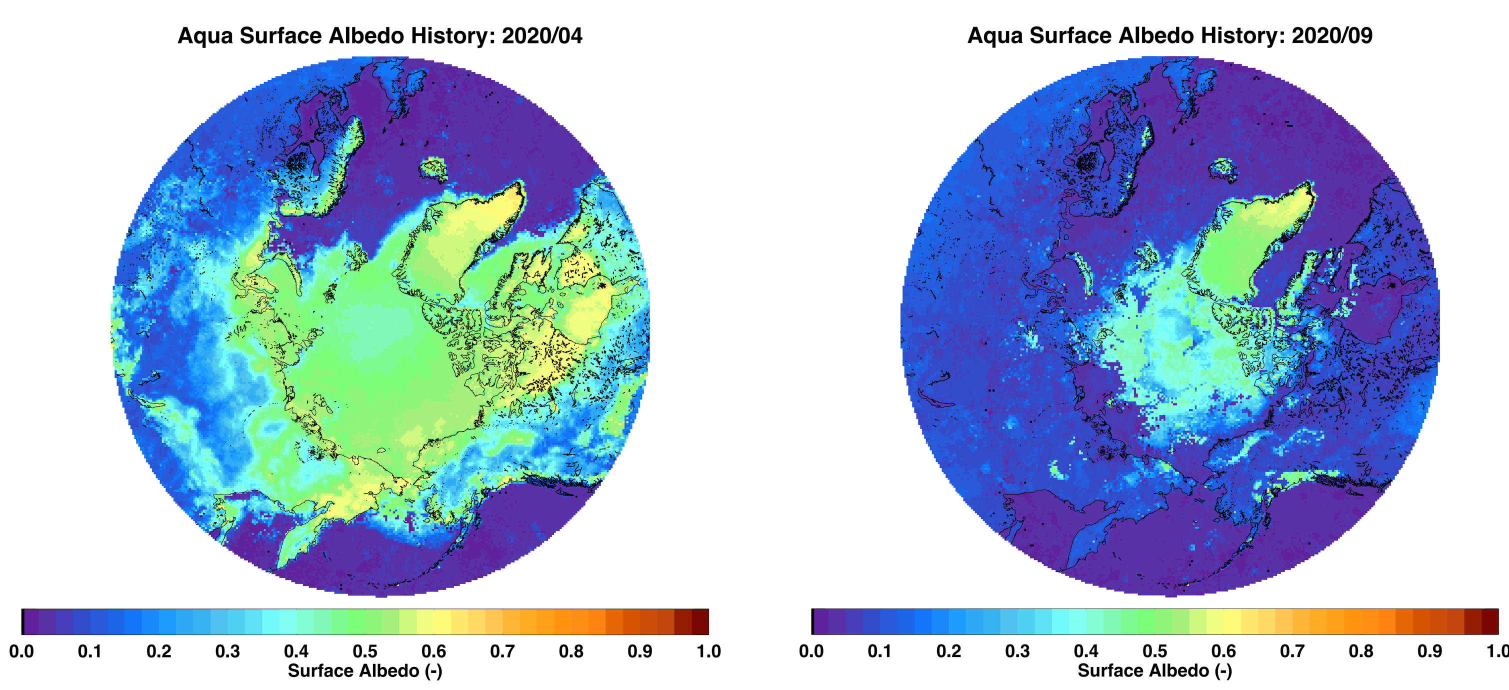
1. Background

The quantification of a surface energy budget for the Arctic is complicated by a changing climate backdrop (especially pronounced in the Arctic), as well as by features such as **seasonal and spatial heteroegenity** (often at the sub-grid scale), the **lack of shortwave radiation during winter**, **high albedo differences** of snowy versus icy versus ice-free surfaces, and a **dependency on radiative transfer model outputs and meteorological variables** from satellites and reanalysis.

Surface albedo "history maps": a-priori surface albedo maps for each of NASA's Clouds and the Earth's Radiant Energy System (CERES) grid boxes using CERES top of atmosphere observations as the initial albedo in the Cloud Radiative Swath (CRS) radiative transfer calculation (referenced in Section 2). Sample maps below show the high degree of spatial resolution available across the MOSAiC study area (monthly temporal resolution). Among a selection of key variables investigated by Rutan et al. (2009), this process showed a large sensitivity to changes in precipitable water, specifically over snowy surfaces, so this variable is of interest for Section 4.



Rutan, D. A., F. G. Rose, M. Roman, N. Manalo-Smith, C. Schaaf, and T. Charlock (2009): Development and assessment of broadband surface albedo from Clouds and the Earth's Radiant Energy System Clouds and Radiation Swath data product. *J. Geophys. Res.: Atmos*, 114(D8), 1-19.

"The CERES Synoptic 1degree (SYN1deg) product **overestimates** the downwelling shortwave flux…and **underestimates** the upwelling shortwave flux…at the surface during summer…[perhaps because] the atmosphere represented in CERES is too optically thin. The large negative bias in upwelling shortwave flux can be attributed in large part to **lower surface albedo**…in satellite footprint relative to surface sensors."

Huang, Y., P. C. Taylor, F. G. Rose, D. A. Rutan, M. D. Shupe, M. A. Webster, and M. M. Smith (2022). Toward a more realistic representation of surface albedo in NASA CERES-derived surface radiative fluxes: A comparison with the MOSAiC field campaign

NASA's CERES group provides CRS satellite data collocated at a footprint level across time and space with MOSAiC. This study aims to use this data to examine how well it agrees with MOSAiC and whether surface albedo improves under certain regimes.

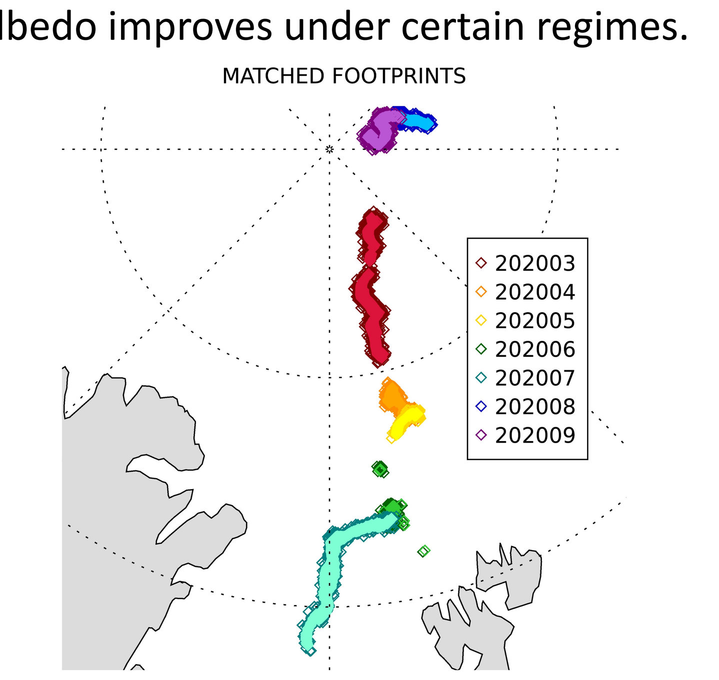
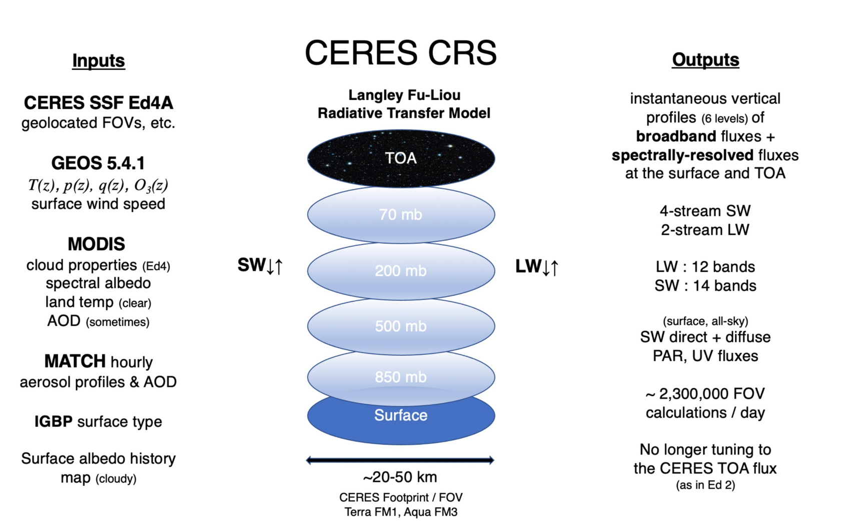


Figure above shows MOSAiC data locations (lighter hues) with corresponding CRS footprint locations (darker hues).

2. Data

Surface-level meteorological properties: albedo, shortwave upgoing (SWUP) and downgoing (SWDN) radiation, temperature (T_{SFC}) captured during **MOSAiC** ("Met City", ASFS sleds)

Surface albedo, SWUP, SWDN, T_{SFC}, precipitable water (PW) captured by **NASA's CERES CRS** product. Cloud fraction (CF) and sea ice concentration (SIC) from **CERES Single Scanner Footprint (SSF)** product.



Schematic from Scott, R. C.; F. G. Rose; P. W. Stackhouse, Jr.; N. G. Loeb, S. Kato, D. R. Doelling, D. A. Rutan, and P. C. Taylor (2022). Clouds and the Earth's Radiant Energy System (CERES) Cloud Radiative Swath (CRS) Edition 4 Data Product. *J. Atmos. And Ocean. Tech.*, 39(11), 1781-1797.

CERES products located at https://ceres.larc.nasa.gov/data. SSF presently available; CRS availability is imminent.

3. How well do MOSAiC and CRS agree?

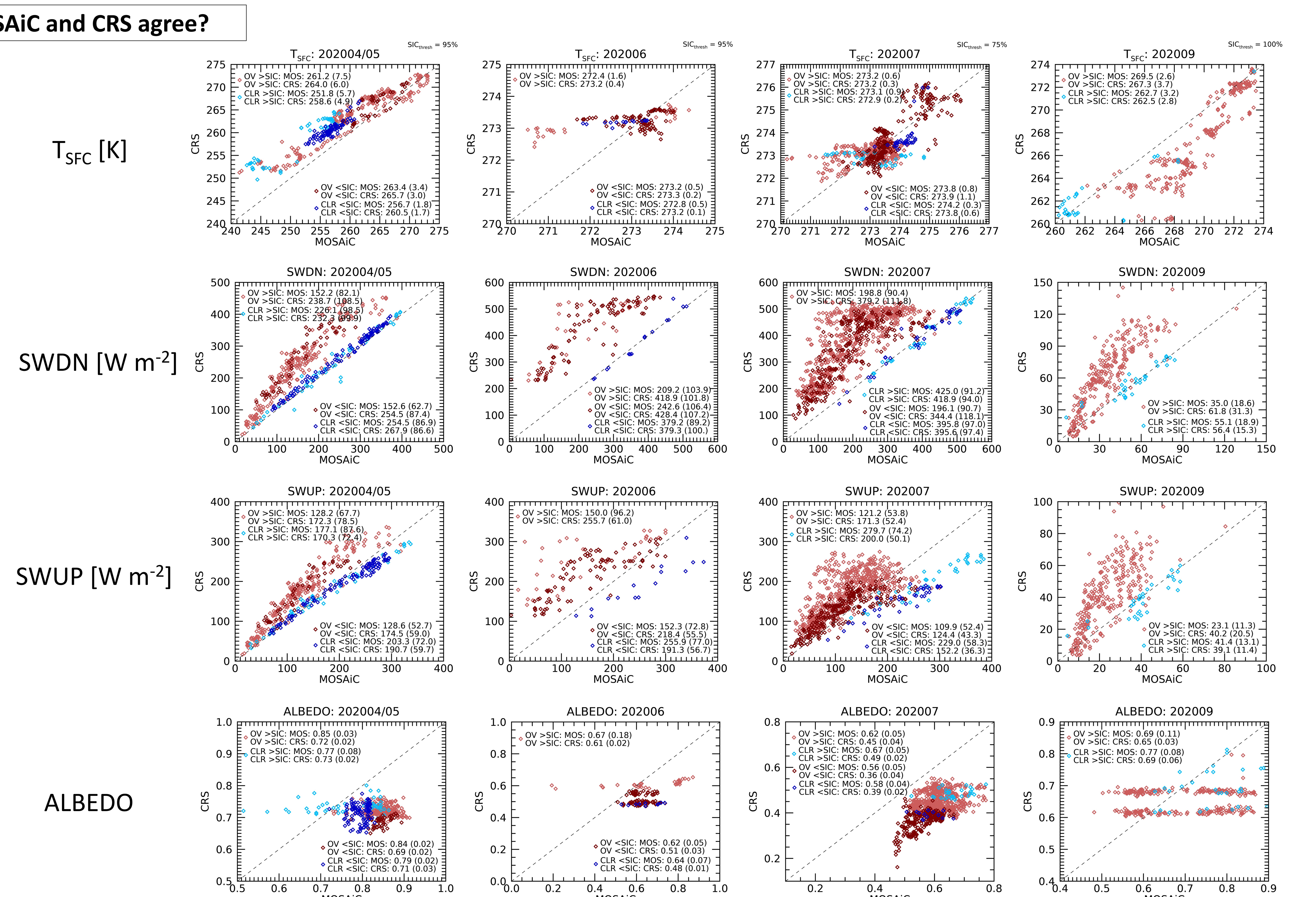
Figures to the right show individual CRS footprint data for a given variable paired with the corresponding average of MOSAiC (MOS; Met City and ASFS sites) data collected within the same hour and within 20 km of the CRS footprint (based off CERES footprint).

Values shown on figures are mean (standard deviation).

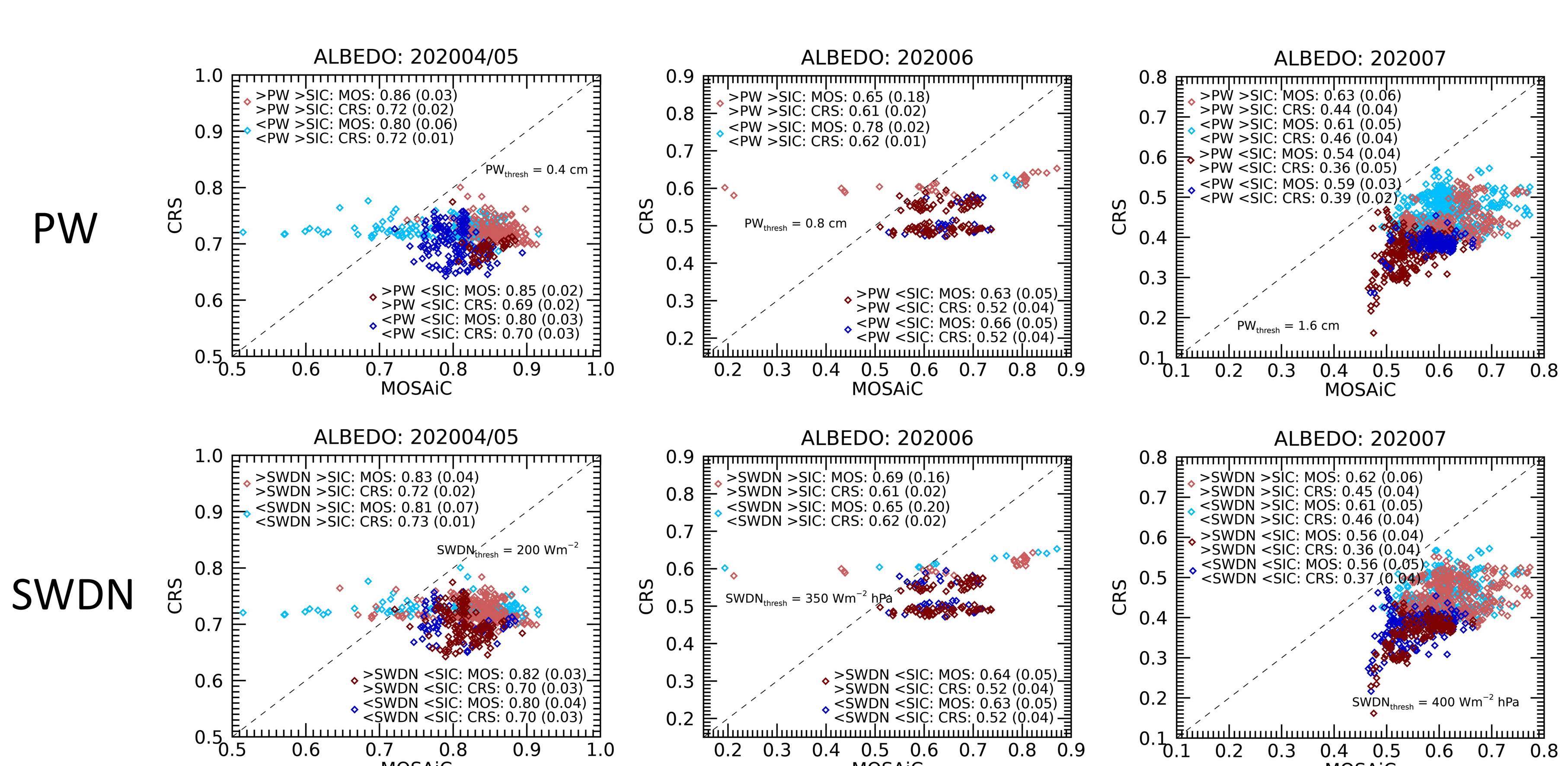
Overcast "OV" (clear "CLR") conditions are shown in red (blue) hues, and are defined as footprints where total CF exceeds 90% (is less than 10%).

Darker (lighter) hues correspond to less (more) icy footprints and are denoted as "<SIC" (">SIC"), with thresholds shown in the upper right of the top row panels.

202004 and 202005 are combined due to strong similarities in trends. 202008 is omitted due to lack of data pairings (MOSAiC transit period).



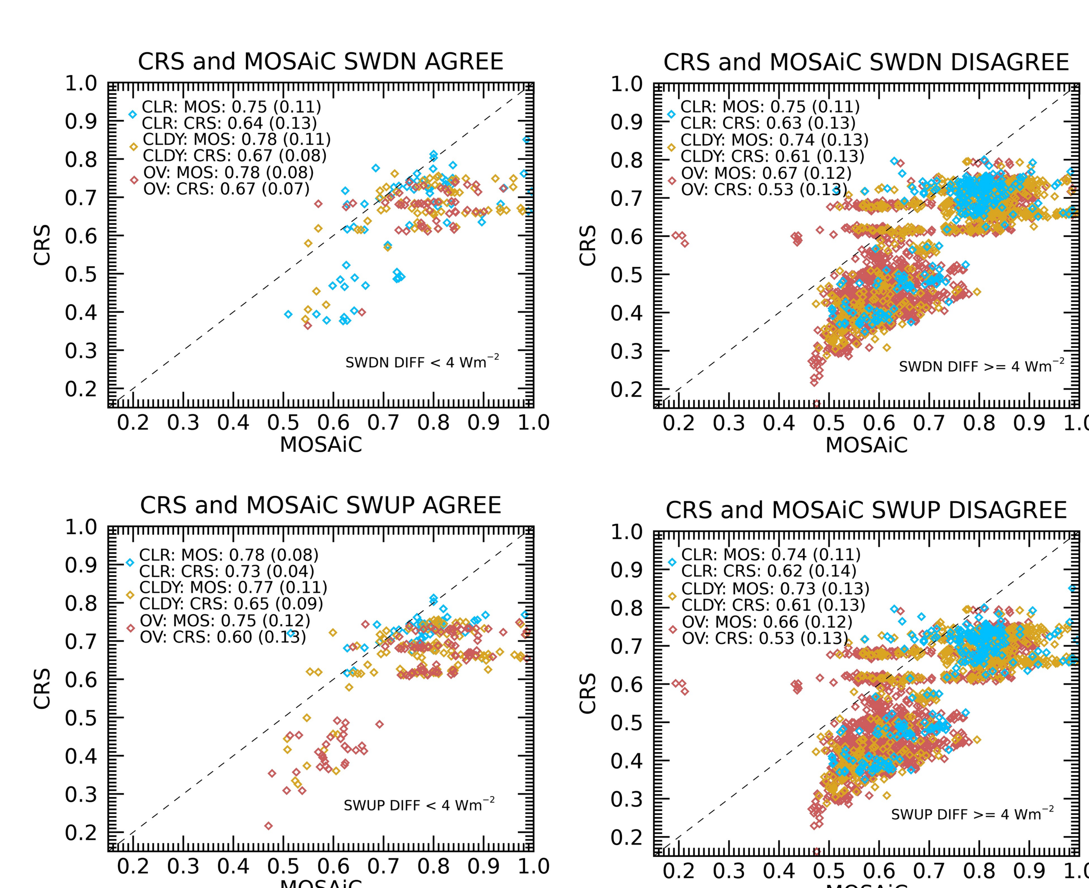
4. Is the approximation of albedo better under certain conditions?



Figures above show CRS and MOS surface albedo pairings when partitioned by relative higher/lower PW (top row) and surface SWDN (bottom row). Thresholds (shown on each figure) are selected for each variable and time frame, and data points are identified as being either above (e.g. ">PW") or below ("<PW") the stated threshold. As before, darker (lighter) hues correspond to less icy "<SIC" (more icy ">SIC") footprints, with SIC thresholds kept constant from section 3.

Months 202004-202007 (columns) are selected for range of SIC available for comparison.

Figures below show surface albedo pairings partitioned based on when CRS and MOS agree (left) or disagree (right) on SWDN (top) or SWUP (bottom) at the given location. Clear (CLR, <10% CF), cloudy (CLDY, 10-90% CF), and overcast (OV, >90% CF) conditions are shown separately.



5. Conclusions

- Despite a lack of precision (likely attributable to resolution) mean values for T_{SFC} indicate high accuracy.
- SWDN and SWUP are largely overestimated by CRS in overcast conditions, but clear conditions have much stronger correlation (independent of surface type). In summer, less accuracy in SWUP under clear conditions may be attributable to greater variability in SIC/surface type.
- No clear trend in albedo agreement when partitioning points by high or low PW/SWDN.
- Despite strong agreement between CRS and MOS in SWDN under clear conditions, this does not yield significantly greater accuracy in albedo.
- No correlation between SWUP agreement and albedo under cloudy or overcast conditions.
- Scale is important!